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4 DRAWINGS - RI/FS STURGIS WELL FIELD (2), RI STATE DISPOSAL LANDFILL (2)
5 MAPS - RI WAUSAU WATER SUPPLY SITE

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WARZYN

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Waste Management Division
U.S. EPA, REGION V

December 2, 1991

Mr. Paul Takacs
Illinois Environmental Protection Agency
Division of Land Pollution Control
2200 Churchill Road
Springfield, Illinois 62794-9276

Re: Vertical Water Quality Profiling References

Dear Mr. Takacs and Mr. Williamson:

The enclosures are excerpts from three RIs and a paper describing the methods and results for collecting groundwater quality samples while drilling. Each of the RIs were conducted by Warzyn under a QAPP approved by EPA Region V. Each of the RI's used different methods for drilling and sampling depending on the geology, depth of contamination and the drilling techniques available. The drilling and sampling methods proposed for the deep borings at Beloit Corporation were used at State Disposal. However, the primary point is that several methods are feasible and each has been demonstrated to be effective in characterizing groundwater quality.

If you have any questions regarding this material, please do not hesitate to contact us.

Sincerely,

WARZYN INC.

James E. Moser
Hydrogeologist

Kenneth J. Quinn
Senior Manager

JEM/mpb/KJQ
[mad-112-179a]
15268.02

Enclosures: As Stated

cc: Michael Radcliffe - Beloit Corporation
Wayde Hartwick - U.S. EPA

THE PERFECT BALANCE
BETWEEN TECHNOLOGY
AND CREATIVITY.

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ONE SCIENCE COURT
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WARZYN

Technical Memorandum 13076

Phase I Remedial Investigation
Wausau Water Supply NPL Site
Wausau, Wisconsin

Prepared for:

United States Environmental Protection Agency
Region V
Chicago, Illinois

Prepared by:

Warzyn Engineering Inc.
Madison, Wisconsin

April 1988

and R3 indicated downward gradients in the vicinity of the creek. Therefore, Bos Creek was identified as a potential source of VOC contamination to the shallow aquifer. Surface water samples were collected from Bos Creek to determine if discharge from production well CW6 was affecting groundwater quality through induced recharge of surface water into the aquifer. The collection and analysis of surface water supplemented groundwater data collected from adjacent wells.

2. Sample Collection Procedures

Surface water samples were collected by slowly submerging a 40 mL VOA vial into the surface water body while standing on shore. The vial was then capped so that no headspace remained. Samples were transported to the on-site GC within 1 hour. Duplicate samples of stations SW09 and SW10 were collected and submitted to the CLP for verification of field GC results.

F. DRILLING AND MONITORING WELL INSTALLATION (Task 2.1.6)

The subsurface exploration and groundwater monitoring well installation program was conducted between October 12 and December 12, 1987. Drilling, soil sampling, monitoring well installation and groundwater sampling while drilling was performed by Wisconsin Test Drilling, Inc. (WTD) of Schofield, Wisconsin, under the supervision of Warzyn.

Warzyn field personnel recorded activities in log books, prepared boring logs, collected soil and groundwater samples during drilling, and acted as safety officers at their respective drilling rigs.

Twelve (12) monitoring wells were installed at eight (8) locations in the west well field area and eighteen (18) wells were installed at thirteen (13) locations in the east well field area. An additional six (6) shallow soil borings were conducted in the east well field area in order to obtain shallow soil and groundwater samples for field and laboratory VOC analysis. Monitoring well and boring well locations are presented in Drawing 13076-B11. Boring logs and well details are presented in Appendices B and C, respectively.

1. Purpose

Monitoring wells were installed to provide data on aquifer characteristics, groundwater quality and groundwater flow directions. The nested wells provide information on vertical groundwater gradients and water quality at depth in the aquifer. Well nests generally included a shallow water table well, installed in the upper aquifer, and a deep piezometer installed near the base of the aquifer. Well locations and depths were modified from planned locations outlined in the Work Plan based on results of Round 1 water quality analyses, field VOC analyses of soil gas and water samples collected during drilling, and results of the preliminary groundwater model. The well locations selected were agreed upon with the U.S. EPA Project Officer. Refer to Table 6 for summary of well location and depth rationale.

2. Drilling Equipment

WTD provided drilling rigs, (CME 45C, CME 750, CME 55, D 50 and Canterra CT 311), associated tools, rig operators and support personnel, steam cleaning equipment, soil sampling equipment, groundwater sampling drivepoint and riser, and well construction materials. WTD also provided two Brainard Kilman (BK) 1.7 inch hand pumps for groundwater sampling during drilling. Warzyn provided a Johnson-Keck submersible pump with packer for sampling groundwater in deep borings while drilling.

3. Drilling Methods

Drilling required the use of two methods. A 4-1/4 inch I.D. hollow stem auger was used to drill and install shallow water table monitoring wells. A 4-1/4 inch I.D. hollow stem auger with screened lead auger was also used to obtain soil and groundwater samples from shallow borings at locations E32, E33, E34, E35, E36, E37 and E38 (See Drawing 13076-B11).

Deep piezometers were installed using mud rotary methods. A bentonite drilling mud with no dispersing agents (Aquagel Gold Seal) was used to provide the viscosity needed to remove drill cuttings. Four inch I.D. casing was advanced in five foot increments to completion depths in borings E21, E22, E24, E25, E26, W50 and W55 using either a 4-7/8 or a 5-7/8 O.D. roller bit. Water quality analyses conducted during drilling suggested a need for a greater number of deep wells. Due to a shortage in the quantity of available temporary casing, several monitoring wells were drilled without driving casing to the boring completion depth. Borings E20, E27, E30, E31, W52, W53, W54, W56 and W57 were advanced using mud rotary drilling with casing advanced to the water table. Bentonite slurry was used to support the borehole and remove drill cuttings below the water table in these borings. In general, very little drilling fluid was lost to the formation during boring advancement. Well development provided substantial well yields with little or no turbidity. VOC analyses performed on samples obtained during well development indicated VOC concentrations consistent with results obtained from samples collected during drilling (refer to Appendix G).

Water used for drilling well E25 was obtained from the City water distribution system at the filtration plant. This water was analyzed by the field GC and was found to have elevated trihalomethane concentrations (chloroform 50.8 ug/L, see Appendix G results). Subsequently, water for steam cleaning and drilling was obtained from test well CW10. Field GC analysis of water collected from Well CW10 indicated no detectable VOCs (see Appendix G sample CW10). Well CW10 was welded shut prior to drilling well E27, therefore, well E27 was drilled using water from the City distribution system.

4. Soil Sampling

Split spoon soil samples were collected at drilling locations E20 through E31 and W50 through W57, using ASTM method D-1586 (Standard Penetration Test). Samples were generally collected at five foot intervals from the ground surface to a depth of 25 feet. Soil samples were collected at either 10 foot or 15 foot intervals from 25 feet to completion, depending on the proximity of previously sampled borings. Sampling was divided between the shallow and deep boring at each well nest location, as needed, to obtain a complete set of samples for that location. Boring E27 was drilled from ground surface to a depth of 89 feet without soil sampling and was sampled on a 15 foot interval from 89 feet to completion. With the exception of two contract laboratory soil samples collected from 29 to 32 feet, boring E21 was drilled unsampled from ground surface to 89 feet and was sampled on a 15 foot interval from 89 feet to completion depth. Soil samples were collected from auger cuttings at shallow borings E32 through E38. The auger cuttings provided a vertical composite of unsaturated zone soils. These samples were submitted for contract laboratory target compound analysis. Split spoon soil samples were also collected at discrete depth intervals at 12 locations. Refer to Table 7 for soil sample locations, analysis parameters and rationale. The samples were shipped and preserved according to Table 3 of the QAPP. Samples collected for VOC analyses were transferred immediately to the respective bottles without compositing. Grain size samples were also not composited in order to preserve soil texture. Soil samples collected for total organic carbon (TOC) analyses and Acid Base Neutral analyses were composited prior to placement in the sample bottle.

Soil samples recovered from the borings were visually classified in accordance with the United Soil Classification System (USCS). Classifications are preliminary pending results of the physical soil testing and are presented on boring logs in Appendix B. When weather conditions permitted, soil samples were screened for the presence of volatile organic compounds (VOCs) using an HNu photoionization detector (see Boring Logs in Appendix B for results). The HNu photoionization detector is capable of detecting compounds with an ionization potential below 10.2 eV. The instrument was calibrated daily using an HNu calibration gas. HNus were also used to screen drill cuttings for VOCs. Drill cuttings which yielded HNu readings over 1 ppm were contained in 55 gallon drums. The drums were labeled and cross-referenced to field notebooks. The drums are being retained adjacent to the site trailer.

5. Groundwater Sampling

Groundwater samples were generally collected for VOC analysis at 10 or 15 foot intervals below the water table at each monitoring well location. However, a few zones of fine grained soils with relatively low hydraulic conductivity were encountered, from which groundwater samples could not be obtained within a reasonable time period. Because a deep (> 100 feet) plume of VHH was suspected (due to the vertical distribution of contaminants in Monitoring Wells E30 and E31), groundwater samples were not obtained from borings E21 or E27 from depths shallower than 90 feet. However, a water table well (E21A) was installed adjacent to Monitoring Well E21 and was subsequently sampled during the Round 2 sampling event.

Groundwater samples were collected using a three-foot long section of two inch I.D. stainless steel well point attached to a galvanized steel riser pipe. The well point was driven into the base of the borehole so that the slots were exposed to the aquifer. Three casing volumes (or isolated interval) of groundwater were then purged using either a Brainard Kilman 1.7 inch O.D. hand pump or a Johnson-Keck submersible pump with packer. Water samples were collected, for on-site GC analysis, in VOA vials directly from the pump discharge. Several duplicates of these samples were also collected and sent to a CLP lab for verification purposes.

Shallow groundwater samples were obtained from borings E32, E33, E34, E35, E36 and E38 using a screened hollow stem auger which had been drilled several feet into the water table. The sample was collected using either a Brainard Kilman 1.7 inch O.D. hand pump or a stainless steel bailer. Prior to sample collection 3 to 5 casing volumes of water were removed from the auger.

6. Geophysical Logging

Several deep borings were gamma logged using a Mount Sopris 1000 C stratigraphic logger. Results of gamma logging were used to provide information on clay content of penetrated formations and to determine depth to bedrock. Results of the gamma logging were used in combination with the field water quality analyses of samples collected while drilling to optimize well screen location in the aquifer. Logging followed methods outlined in the manual in Appendix E of the QAPP.

7. Well Installation

Water table monitoring wells and piezometers were installed according to construction details contained in Appendix C and summarized in Appendix H. Wells were constructed using 2 inch I.D. flush joint, galvanized steel riser pipe, with No. 10 slot, flush joint, stainless steel screens. Wells screened at the water table were constructed with 10 foot screens. Wells screened at depth in the aquifer, were constructed with 5 foot screens with a 10 foot stainless steel riser pipe directly above the well screen. The annular space between the well and the borehole (sand pack) was backfilled with either No. 30 flint sand, caved formation, or a combination of both. The sand pack generally extended to a height of 3 to 5 feet above the well screen. In cases where the boring extended past the intended location of the screen interval by more than 3 feet, flint sand interbedded with bentonite pellets were used to backfill the borehole so the well screen could be placed at the desired depth in the aquifer. A 2 to 3 foot seal of bentonite pellets was installed above the sand pack of each well. In deep wells, a thick bentonite slurry was used to seal the annular space from the top of the pellet seal to the ground surface. A tremie pipe with lateral exit holes was set above the top of the pellet seal and pumped at a slow rate until the slurry began to run out the top of the auger or casing. Additional bentonite slurry was added as needed to compensate for removed casing. The shallow well annular space was also backfilled with a thick bentonite slurry which was installed from the surface using a pump hose. A surface seal of granular bentonite was installed in the upper 3 to 5 feet of borehole. A locked protective casing was then set into the surface seal. Locked flush mount protective casings were generally installed in driveways, parking lots, City right-of-ways and other highly traveled areas. Cement grout and bumper posts were placed around stick up protective casings adjacent to highly traveled areas. The well installation was completed by marking the protective casing with the well identification numbers.

All wells, with the exception of E28A, appear to function properly. E28A appears to have a slight kink in the screen and therefore must be sampled with a one-inch diameter bailer.

8. Well Development

Shallow wells were developed using either a bailer or a Brainard Kilman 1.7 inch O.D. hand pump. Deep wells were developed using either a Brainard Kilman 1.7 inch O.D. hand pump or a Johnson-Keck submersible pump with packer. Deep wells were surged with a two inch bailer prior to pumping. The pump was also periodically raised and lowered during development, so that the entire screened interval was developed. The well was pumped until a minimum of 10 well volumes had been extracted and the water became visually clear. pH and conductivity were measured at frequent time intervals during development of several wells. In general, changes in theses parameters indicated minimal change after the first two to three well volumes had been removed.

9. Decontamination

Decontamination of well screen, well riser, drive points, drill rig, casing, drill rod, drill bits and other tools consisted of steam cleaning at the decontamination pad. Each drill rig and tools was decontamination prior to start up and between holes. Brainard Kilman hand pumps were also steam cleaned between holes. The Johnson-Keck submersible pump was decontaminated by running Liquinox wash solution through and over the pump for several minutes. Deionized water was circulated through the pump and ran over the tubing for rinse. Water used for steam cleaning was obtained from city test well CW10.

G. GROUNDWATER SAMPLING (ROUND II) (Task 2.1.8)

1. Purpose

Round II groundwater samples were collected from 116 monitoring wells between November 30 and December 12 throughout both the east and west well field areas. Sample locations included the following:

- Five City Production wells (CW3, CW4, CW6, CW7, CW9);
- Two City test wells (Plum Dr. test well, Wilson Hurd test well);
- One private well (Wergin);
- Five Wausau Chemical Extraction Wells (EXW4, EXW5, EXW6, EXW7, EXW15);
- Wausau Chemical treatment system influent and effluent; and
- One hundred and one groundwater monitor wells.

The analytical results obtained from Round II sampling will provide additional data for the RI evaluation, including source identification, extent of contamination and determination of the mass of contaminants present in the aquifer. Results of Round II sampling were not available at the time this document was prepared but will be presented in the Remedial Investigation Report.

2. Sample Collection Procedures

Round II groundwater samples were collected according to procedures described for Round I sampling. Round II groundwater samples were analyzed for VOCs and

WAUSAU WATER SUPPLY NPL SITE
STURGIS WELL FIELD RI/FS
Data Use and Data Quality Objectives for Field Gas Chromatography

The intended data use and data quality objectives (DQO) for Field Gas Chromatography at the Sturgis Well Field RI/FS as described in the Quality Assurance Project Plan (QAPP) were as follows:

- Perchloroethylene and trichloroethylene were the primary target compounds, however, a total of 26 organic compounds were included in the GC screening method.

- The groundwater sample results would be used as a guide for monitoring well location and screen placement.

- Soil gas results would be used to help identify potential sources of contamination, aid in the mapping of contaminant plumes at the water table (if present), and guide the location of monitoring wells.

- Field GC concentration results would be considered estimated, and compound identification would be considered tentative.

- Quality control would consist of the analysis of duplicate samples (results within 15% RPD), and continuing calibration standard analyses (results within 30% RPD).

WARZYN

Remedial Investigation
Report
12686

Sturgis Well Field
Remedial Investigation/ Feasibility Study
Sturgis, Michigan
Volume 3 of 5

Prepared for:
Michigan Department of Natural Resources
Lansing, Michigan

Prepared by:
Warzyn Inc.
Madison, Wisconsin

March 1991

A survey of this property was conducted by Ken Quinn and Tim Melka of Warzyn and Steve Luzkow of MDNR. Sturgis Archery (Mr. Rudy Boals), is the current owner and occupant of the property. The property had remained vacant from 1966, when Wade Electrical closed, until Sturgis Archery purchased it. The Wade Electrical building burned down prior to the time Sturgis Archery purchased the property. Mr. Boals indicated that Wade Electrical had a building which extended the length of the lot on the back 1/2 of the property. After Mr. Boals purchased the property, he had six underground tanks removed from the rear of the property (from under the old building foundation). He reported that the tanks were not leaking and contained small amounts of a thick oily substance. The remains of what appeared to be a fill pipe for the underground tanks (2" steel pipe), was evident up the slope from the tank area, extending from below ground towards the railroad line behind the property.

Mr. Boals indicated that prior to construction of the Wade Electrical Plant the southern portion of the property was occupied by a small church and cemetery.

K. Summary

In summary, the Kirsch Company was the only industry in the survey documented as having used large quantities of TCE (above ground tank at Plant 2). However, it is not known what was stored in the underground tanks at Wade Electrical or used by previous owners of several facilities surveyed. Other small quantity users may currently be located throughout the city.

III. Field Investigation Methods

The field investigation consisted of groundwater monitoring, soil boring, well installation, groundwater quality sampling, and soil gas testing. Little or no information regarding the vertical and horizontal distribution of the groundwater contamination plume or potential source areas was available upon initiation of the field investigation. Limited geologic information was available, prior to initiation of field activities.

A. Monitoring Well, Test Well and Production Well Sampling

Prior to mobilization to the site, sampling pumps, tape measures, bottom loading bailers and stainless steel cable were decontaminated using a trisodium phosphate

(TSP) wash and clear water rinse. Between wells, sampling equipment was decontaminated with a TSP solution wash followed by a rinse with deionized water.

A Johnson-Keck submersible pump was used to sample the existing monitoring wells. A packer was attached to the pump to sample piezometers. The pump was lowered to a depth of approximately five feet above the top of the piezometer screen and the packer was inflated to seal the sampling zone. The sampling interval was then purged of at least three volumes of water in the isolated interval. The sample was collected directly from the pump discharge. The water level above the packer was monitored to assess if the packer continued to be inflated and sealed off the water above the packer. No leakage past the packer was detected in any monitoring well. Purged groundwater was screened with a 10.2 eV HNu photoionization meter for detection of VOCs. None of the purge water collected during sampling had measurable (1 ppm) VOC readings. Therefore, purge water was discharged to the ground surface at the vicinity of each well.

The Johnson-Keck pump was also used to sample water table wells. The pump was lowered to a position about three to four feet above the bottom of the well to prevent possible damage to the pump by fine residual materials which may be present in the well. The well was then purged of at least three well volumes prior to sampling. Samples were collected directly from the pump discharge.

Samples were handled according to methods described in the QAPP, as follows. Sample bottles were labeled at the time of sample collection. Samples were iced immediately upon collection. Sample filtering (as specified in Table 9A of the QAPP) was conducted through a 0.45 mm pressure filtration device as soon as practical after sample collection. Preservation was performed as specified in Tables 9 and 9A of the QAPP.

Temperature, specific electrical conductivity and pH were measured upon sample collection prior to sample filtration and preservation, where appropriate. Replicate VOC samples were collected for on-site analysis by the laboratory gas chromatograph (GC) during Round 1 sampling only. Samples were shipped daily on ice, to the laboratory designated by U.S. EPA's Contract Laboratory Program (CLP) for analysis of VOCs, other organic compounds, metals and/or general water chemistry parameters.

B. Surface Water and Sediment Sampling

Surface water and sediment samples were collected concurrent with Round 1 groundwater sample collection by the groundwater sampling team. Samples were collected from gravel pits, used as storm runoff or effluent discharge points, at Ross Laboratories, Kirsch Company Plant No. 2, and Sturgis Foundry Corp.

Surface water was collected with stainless steel cups prior to collection of sediment samples. The cup was submerged slowly to decrease the turbulence and the potential for volatilization of VOCs. Sediment was collected with a Wildco Sediment Sampler with a stainless steel core barrel. The sampler was pushed into the sediment and retrieved. The sampler contents were placed in a stainless steel bowl. A stainless steel spatula was used to fill the sample jar. Sampling equipment was decontaminated with a TSP wash followed by a deionized water rinse after collection of each sample.

Field pH, specific electrical conductivity and temperature of the surface water samples were measured and recorded upon sample collection. Replicate VOC surface water samples were collected for analysis by the on-site laboratory GC. Samples were preserved, where necessary, and shipped on ice to the CLP lab daily as specified in Tables 9 and 9A of the QAPP.

D. Soil Gas Sampling

Soil gas sampling was performed in four rounds. Round One was performed between September 8 and 16, 1987 and involved collection and analysis of 137 samples. Round Two sampling was performed October 26 through October 28, 1987. A total of 48 samples were collected and analyzed during Round Two. Round three sampling was performed between June 21 and June 27, 1988. A total of 96 samples were collected and analyzed during Round Three. Round Four sampling was performed between July 25 and July 27, 1988. A total of 18 samples were collected and analyzed during Round Four.

The soil gas sampling vessels were glass cylinders fitted with teflon stopcocks at either end. These vessels were decontaminated prior to and between samples by purging with ultra-pure helium gas. Prior to use, each sampling tube was again purged with helium for a minimum of 30 seconds.

Sampling consisted of driving a rod to a depth of approximately 3 feet. The drive rod was removed from the ground and the sampling probe was inserted into the hole made by the drive rod to a depth of approximately 2.5 ft. One and a half volumes of the sampling tube, probe and sample vial was purged using a calibrated air pump. The stopcocks on the sampling tube were closed and the air pump was turned off. The sampling tube was wrapped in aluminum foil, to prevent photo-chemical alteration of the gas sample, and was stored on ice until analysis.

Duplicate and blank samples were also collected and analyzed. A sample was also collected daily from a known hot spot (SG-5) to be used as a sensitivity check for changing weather conditions.

E. Field Analytical Methods for VOCs

Field GC analytical methods for soil gas, water headspace and soil headspace samples were intended to provide for detection and quantitation of the following compounds:

- benzene
- bromodichloromethane
- bromoform
- chloroform
- chlorodibromomethane
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,1-dichloroethene*
- 1,2-dichloroethenes*
- ethyl benzene
- methylene chloride
- tetrachloroethene*
- toluene*
- 1,1,1-trichloroethane
- trichloroethene*

*Target Compounds

Field analysis was performed according to the methods listed in Appendix G of the approved QAPP. The method referenced in Appendix G differed between the approved QAPP and the Appendix G submitted by Warzyn with the QAPP signature page to Mr. Steve Luzkow on November 6, 1987. The method references provide the foundation on which to develop a new method. In development of the field GC screening procedure, no single reference is applicable. The headspace preparation step (method 3810) was included in Warzyn's November 6, 1987 Appendix G as a reference because it was used in developing the method. After that either combination (601/602 or 8010/8020) could be referenced for the instrumental analysis portion of the method. Both combinations provide similar methodology. For consistency with RCRA methods (rather than wastewater methods) 3810, 8010 and 8020 were referenced in Warzyn's November 6, 1987 Appendix G.

A Varian 3400 model GC was used with dual detectors (PID/HECD) in series. Each analytical run (one field day or less) included a standard sequence consisting of a 4-point standard curve for headspace target compounds (50, 10, 5, and 1 ug/L), a headspace blank of a 50 ug/L headspace non-target compound and 5 ul injections of both target and non-target compounds for soil gas. Every eleventh analysis thereafter and the last sample each day were continuing calibration standards. Continuing calibration standards were required to be within ±30% of the original standard, or a new standard curve was prepared and samples analyzed since the previous check standard were reanalyzed. Duplicate analytical samples were analyzed on a 1 in 10 or fewer basis.

Water and soil samples were collected in 40 mL vials with open screw-caps and teflon faced silicone septa. Water samples were collected so that no headspace remained in the vial. Soil gas samples were collected in 250 mL glass vessels. All samples were protected from sunlight, kept in coolers, and transported to the field laboratory as soon as possible.

When received by the field laboratory, soil gas bulbs were allowed to equilibrate to ambient air temperature. A 5 mL aliquot (or smaller for dilutions) of sample was removed through the sampling septa and injected into the GC.

Just before analysis, water samples were uncapped and 10 mL of sample was removed from the vial. The vial was then recapped and placed in a 55°C water bath for 10 minutes for headspace equilibration. A 5 mL aliquot of headspace air was removed from the vial through the septa and injected into the GC. Headspace dilutions were made by bringing an aliquot of the sample to 40 mL with organic free-water in a new 40 ml vial and repeating the above procedure.

Soil sample analysis by the field laboratory consisted of quickly uncapping the sample vial, transferring 10 grams of sample to a 40 mL vial, adding 20 mL of deionized water and recapping the vials. The vial was placed in a 55°C water bath for 10 minutes to allow the headspace to equilibrate. A 5 mL aliquot of headspace was removed from the vial through the septa and injected into the GC. Dilutions were performed on soil by repeating the above procedure with a smaller sample size. Dilutions for both soil and water were sometimes made immediately where high concentrations of VOCs were anticipated, due to field HNu readings provided by the drill rig observer.

Concentrations of target headspace VOCs were calculated based on a linear regression obtained from the initial calibration curve. Nontarget headspace and soil gas results were calculated on the basis of a 1-point standard. Concentrations in water were calculated according to the equations in Appendix G of the approved QAPP. Calculations in the field were performed according to the equation in the approved QAPP using two steps and the following equations:

$$\text{ng(injected)} = \frac{\text{R(samp)} \times \text{ng(Std)}}{\text{R(std)}} \qquad (1)$$

where: ng(injected) = nanograms of compound injected
R(samp) = response of compound in sample
ng(Std) = nanograms of standard injected
R(std) = response of compound in standard

$$\text{ng/L} = \frac{\text{ng(injected)} \times 1000\ \text{mL/L}}{\text{Va}} \qquad (2)$$

where: ng/L = nanograms of compound per liter of soil gas
ng(injected) = nanograms of compound injected from equation 1
Va = volume of soil gas injected

Results for equation (2) where calculated at the end of the day on a summary page in the field laboratory notebook

Sample results, standard conditions and notes were recorded in a bound log book. Field results of GC analyses were considered tentatively identified with estimated concentrations.

F. Soil Boring and Monitoring Well Installation Methods

The Phase I subsurface exploration and groundwater monitoring well installation program was conducted between September 8 and October 29, 1987. With the exception of Wells W-2I and W-2D, Exploration Technology Inc. (ETI) was contracted to perform the drilling, monitoring well installation and soil sampling at all wells installed during Phase I. Wells W-2I and W-2D were drilled and installed by Keck Consulting Services (KCS). The Phase II drilling program occurred between June 21 and September 22, 1988. The Phase IIB drilling was performed between May 1 and July 12, 1989 by John Mathes and Assoc., Inc. (Mathes). Mathes was contracted to perform Phase II and Phase IIB drilling, well installation, soil borings and soil sampling. Personnel overseeing drilling activities recorded activities in log books, kept boring logs, collected soil and groundwater samples during drilling, and acted as safety officers at their respective drilling rigs.

ETI, KCS and Mathes provided drilling rigs and associated tools, rig operators and support personnel, steam cleaning equipment, soil sampling equipment, pumps and well construction materials used in the investigation.

Drilling required the use of three methods. 4 1/4 inch inside diameter hollow stem augers were used for the following:

- Drilling shallow water table wells,
- Drilling the initial 60 ft for Phase I piezometer wells installed by ETI,
- The drilling method for the Phase I piezometers installed by KCS,
- Drilling soil borings (Phase II and Phase IIB).

The lead section of the hollow stem auger was screened to allow collection of water samples and to minimize head differences between the formation and inside the augers. When necessary, rotary wash boring methods were used inside the augers to clear sand which had blown up into the augers during drilling. Wash boring through the hollow stem augers allowed collection of representative split spoon soil samples, groundwater samples and well installation.

Water used for wash borings, and steam cleaning was obtained from a hydrant near the operations headquarters. This water was periodically analyzed by the field GC and shown to be clean.

A combination of clear water and mud rotary drilling was used by ETI to install Phase I deep piezometers. 4 1/4 inch inside diameter (I.D.) hollow stem augers were drilled to a maximum depth of 60 ft or to the top of a shallow initial confining layer, if present at a specific location. The hollow stem augers were removed, and a six inch I.D. temporary casing was drilled into place using wash boring techniques. A five inch I.D. temporary casing was telescoped through the six inch casing. The hole was advanced in five foot increments using a 4 7/8 outside diameter (O.D.) roller bit, recirculating clear water or a solution with a minimal amount of drilling mud, followed by driving the five inch I.D. casing. A four inch I.D. temporary casing was telescoped through the five inch casing upon encountering a confining layer. At the interface with a confining layer, five inch casing was pushed into a bentonite pellet seal, prior to telescoping the four inch casing, to attempt to limit potential cross contamination between aquifers. Four inch casing was advanced in five foot increments using a 3 7/8 O.D. roller bit. During drilling it became apparent that the clear water wash method was insufficient to flush coarse drill cuttings from the borehole. MDNR permitted the use of a thin drilling mud to provide the viscosity needed to clear coarse materials from the borehole.

Deep wells drilled by KCS used 4 1/4 inch I.D. hollow stem augers. KCS drilled one hole to collect stratigraphic data and a second hole with a polypropylene plug in the augers to collect water quality data. The first borehole was abandoned with a thick bentonite slurry upon completion. After knocking out the polypropylene plug at the bottom of the borehole, the deep well was installed.

Deep wells were installed during Phase II and Phase IIB by Mathes using air rotary drilling methods. An 8-inch permanent casing was driven into the upper-most confining layer at a given drilling location, except at well nests W2 and W32, where eight inch casing was set at greater depths due to the absence of confining layers. At locations where VOCs were not detected in the upper aquifer, eight inch casing was advanced through the upper confining unit and middle aquifer into the middle confining unit. At the interface with a confining layer the eight inch casing was set into a bentonite pellet seal, and six inch permanent casing was telescoped through the bentonite pellet seal and eight inch casing to advance the borehole. The method used in Phase II and Phase IIB was similar to the method of Phase I, with the exception of using air to clear cuttings from the borehole, and the installation of permanent well casing in Phase II and Phase IIB. Mud rotary methods were also used to advance the Phase IIB borehole at well location W5DD and W41D, due to difficult drilling conditions.

Split spoon soil samples were collected at each Phase I drilling location and at shallow Phase II and Phase IIB drilling locations, using ASTM Method D-1586, for soil classification purposes. Samples were collected at shallow well locations at five foot intervals from the ground surface to a depth of 30 feet, and at ten foot intervals from 30 feet to the terminus of the borehole. Samples were collected from soil boring locations at 2 1/2 foot intervals from ground surface to 10 feet, and at five foot intervals from 10 to 30 feet. The Phase II and Phase IIB air rotary borings were not sampled with split spoons. Drill cuttings, integrated over a wide (10 to 20 ft) zone were visually classified by the rig geologist.

Soil samples collected above the water table were used for on-site analysis of VOCs. Samples were analyzed by the lab GC using a headspace analysis method. Contaminated drill cuttings, defined as greater than a 5 ppm reading on the HNu, were contained in 55-gal drums. The top two soil samples from each soil boring were shipped to CLP for target compound list/target analyte list (TCL/TAL) analysis. The remaining soil samples collected from each boring were shipped to CLP for VOC analysis.

Phase I and Phase II groundwater samples were collected for VOC analysis at 10 foot intervals below the water table except in zones of fine grained, relatively low hydraulic conductivity, soils. Phase IIB groundwater samples were collected at predetermined depths, based on results of Phases I and II and as specified in the Phase IIB QAPP. In Phase I, ETI used a groundwater sampling point constructed of a three-foot long section of two inch I.D. stainless steel well point attached to a galvanized steel riser pipe. The well point was driven ahead of the casing and was purged of at least three casing volumes of groundwater using a Brainard Kilman 1.7 inch O.D. hand pump. Water samples were collected, for on-site GC analysis, in VOA vials directly from the pump discharge. Several of these samples were sent to CLP for method verification purposes.

KCS used a screened lead auger for groundwater sampling during drilling. An air line placed above the screened auger was used to purge a minimum of three volumes of groundwater from the augers. The air line was removed and a submersible Johnson-Keck (JK) pump was used to purge the augers for an additional 15 minutes prior to sample collection. Where practical, a four inch submersible or the Johnson-Keck pump and a packer were used to purge and collect the sample.

Mathes used a four inch submersible pump and/or 10-ft long PVC bailers to purge a minimum of three volumes of groundwater from the drive casing. The purging tools were removed, and a JK pump was used to purge the casing for an additional 15 minutes prior to sample collection.

Each deep boring performing during drilling was gamma logged using a Mount Sopris 1000C logger upon reaching the terminus of the borehole. Results of gamma logging were used to provide an indication of the presence of confining units within penetrated formations. Results of the gamma logging were used in combination with the field water quality analyses of samples collected while drilling to optimize well screen location in the aquifer.

Groundwater monitoring wells were installed upon reaching the terminus of each borehole. Wells were constructed using 2 inch I.D. flush joint, galvanized steel riser pipe, with No. 10 slot, flush joint, stainless steel screens. Wells screened at the water table were constructed with 10 foot screens. Piezometers, wells screened at depth in the aquifer, were constructed with 5 foot screens. Piezometers were constructed with a 10 foot stainless steel riser pipe directly above the well screen.

The wells were installed with the driven casing or augers in place with removal of the ETI casing or augers progressing as the annular space was backfilled. The casing used by Mathes was installed as permanent casing with the inner casing lifted approximately seven ft above the bottom of the well screen to expose the screen to the formation. The annular space between the well and edge of the borehole was packed with either No. 30 flint sand, caved formation or a combination of both, to a height of 3 to 5 ft above the well screen. In cases where the boring extended past the intended location of the screened interval by more than 3 ft, flint sand interbedded with bentonite pellets was used to backfill the borehole so the well screen could be placed at the desired depth in the aquifer. If the boring extended less than 3 ft into clay soils, sand was used to backfill the borehole to the top of the clay prior to well screen placement.

A 2 to 3 foot seal of bentonite pellets was installed above the sand pack of each well. Where permanent casing was installed, the pellet seal was extended into the bottom of the permanent casing. In deep wells, a thick bentonite slurry was used to seal the annular space from the top of the pellet seal to the ground surface. The tremie pipe used for slurry injection was set above the top of the pellet seal and pumped at a slow rate until slurry began to run out of the top of the auger (for the KCS wells) or the casing (for the ETI and Mathes wells). Additional slurry was added, upon removal of each section of casing (ETI) or auger, up to the water table.

In all wells, a mixture of clean sand and granular bentonite was added to the borehole from the water table to a depth of 2 to 3 feet below ground surface. A surface seal of granular bentonite, accompanied by a 4.5 foot long or flush-mounted locked protective casing set into the surface seal, finished the installation. Protective casings were marked with well identification numbers.

WAUSAU WATER SUPPLY NPL SITE
STURGIS WELL FIELD RI/FS
Data Use and Data Quality Objectives for Field Gas Chromatography

The intended data use and data quality objectives (DQO) for Field Gas Chromatography at the Sturgis Well Field RI/FS as described in the Quality Assurance Project Plan (QAPP) were as follows:

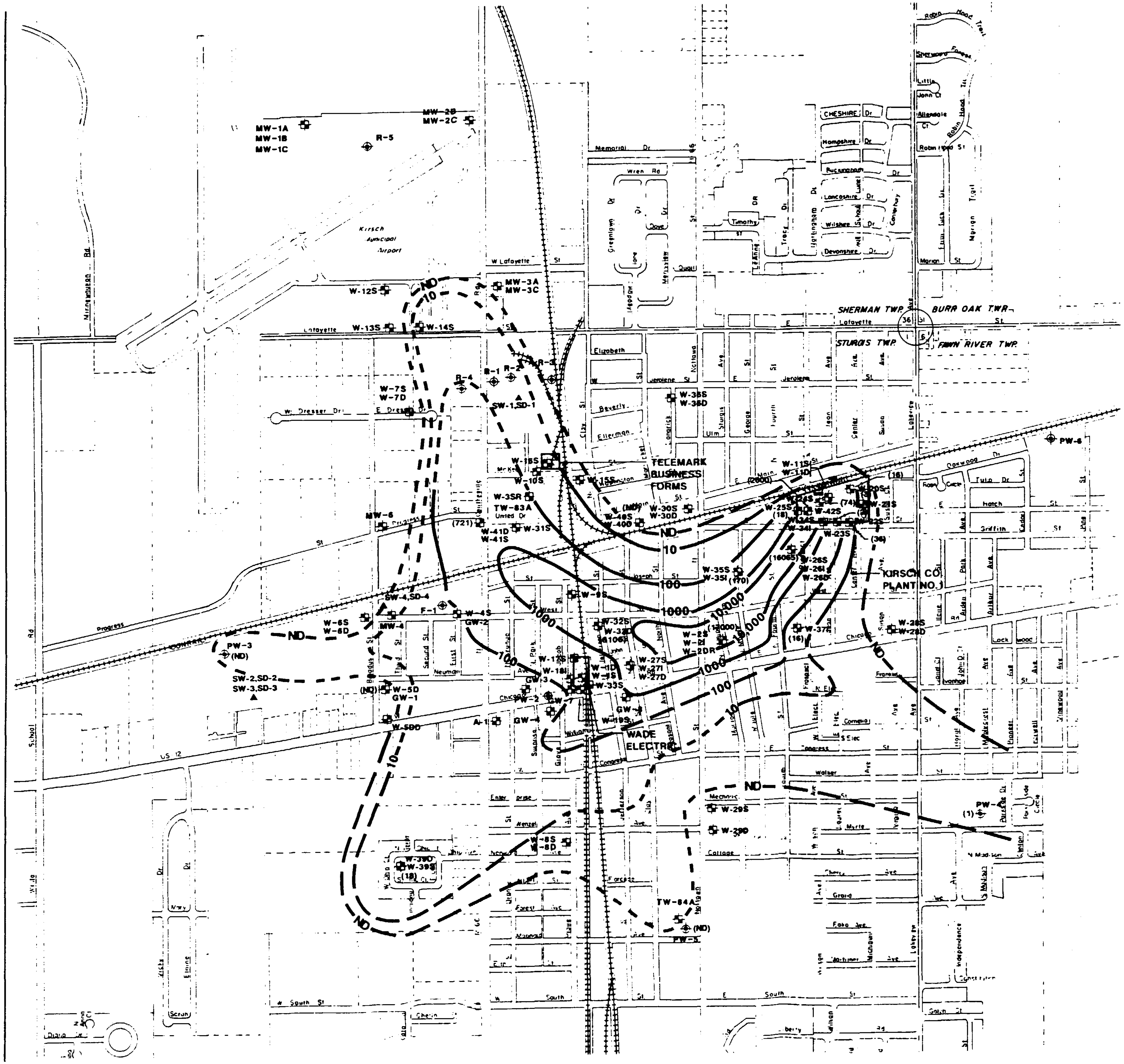
- Perchloroethylene and trichloroethylene were the primary target compounds, however, a total of 26 organic compounds were included in the GC screening method.

- The groundwater sample results would be used as a guide for monitoring well location and screen placement.

- Soil gas results would be used to help identify potential sources of contamination, aid in the mapping of contaminant plumes at the water table (if present), and guide the location of monitoring wells.

- Field GC concentration results would be considered estimated, and compound identification would be considered tentative.

- Quality control would consist of the analysis of duplicate samples (results within 15% RPD), and continuing calibration standard analyses (results within 30% RPD).



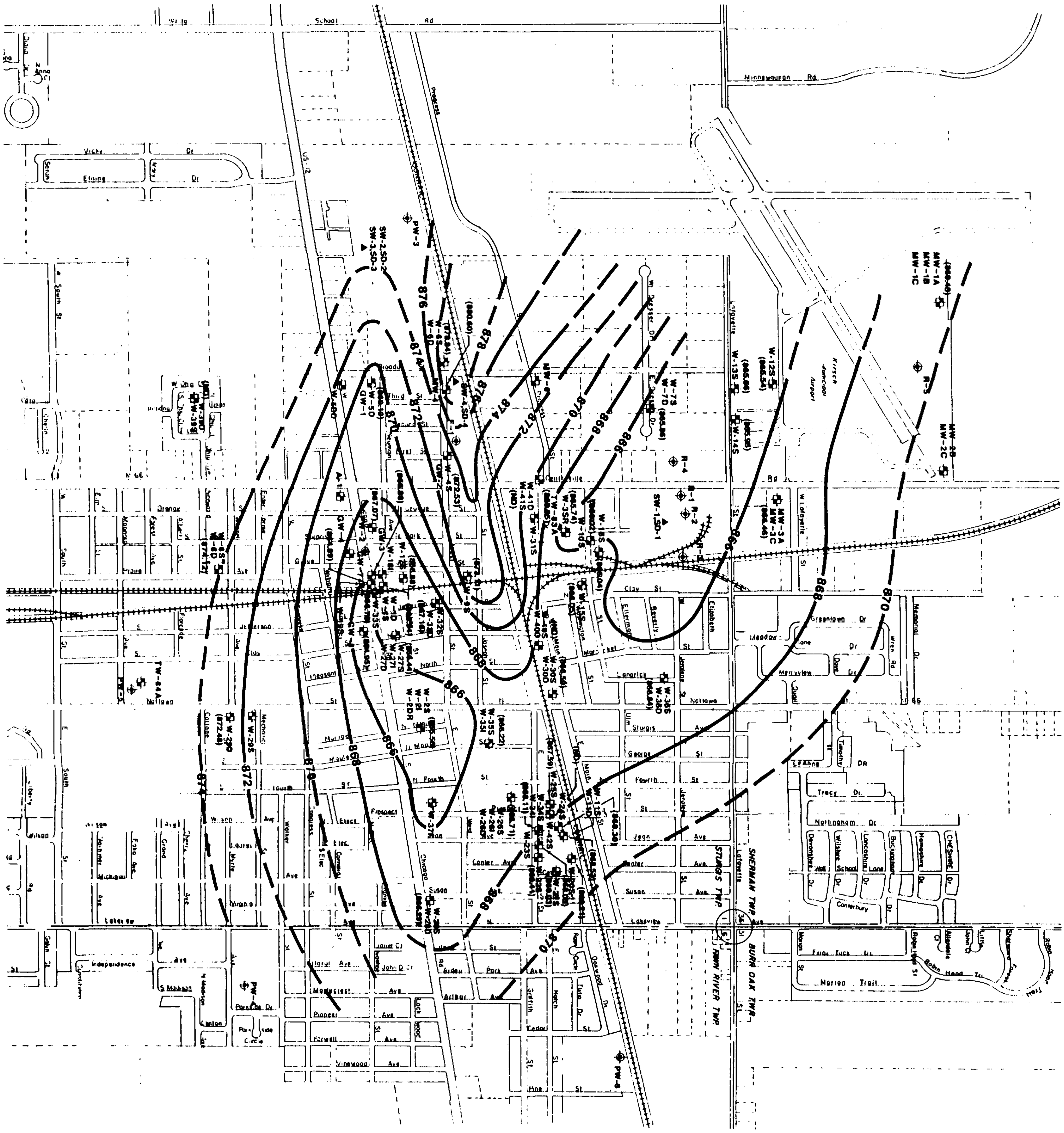
LEGEND

- SW-1 / SD-1 ▲ — APPROXIMATE SURFACE WATER AND SEDIMENT SAMPLING LOCATION AND NUMBER
- (17,000) W-2DR — EXISTING MONITORING WELL LOCATION, NUMBER AND CONCENTRATION OF TOTAL CHLORINATED ETHENES
- (1) PW-4 — PRODUCTION WELL LOCATION, NUMBER AND CONCENTRATION OF TOTAL CHLORINATED ETHENES
- RAILROAD TRACKS
- PAVED ROAD
- —100— ISOCONCENTRATION CONTOUR (DASHED WHERE INFERRED)
- IMPLIED ISOCONCENTRATION CONTOUR (BASED ON PREVIOUS ANALYTICAL RESULTS)
- (ND) COMPOUNDS NOT DETECTED
- APPROXIMATE FACILITY AREA BOUNDARY

NOTES

1. SEE DRAWING 12686-5 FOR ADDITIONAL NOTES AND LEGEND.
2. TOTAL CHLORINATED ETHENE COMPOUNDS INCLUDED IN THIS DRAWING ARE 1,1-DICHLOROETHENE, TOTAL - 1,2-DICHLOROETHENE, TRICHLOROETHENE AND TETRACHLOROETHENE.
3. CONCENTRATIONS ARE IN ug/L.
4. RESULTS SHOWN ARE FROM GROUNDWATER SAMPLES COLLECTED BY WARZYN ENGINEERING INC. DURING ROUND 4 GROUNDWATER SAMPLING (AUGUST 1989). SAMPLES WERE ANALYZYED THROUGH THE U.S. EPA CONTRACT LABORATORY PROGRAM.
5. IMPLIED (SHORT DASHED) CONTOURS INCLUDE ESTIMATES OF CONCENTRATION BASED ON PREVIOUS SAMPLING EVENTS.

CONTAMINANT PLUME (AUGUST 1989)	Revisions / Date · By · Apprd
REMEDIAL INVESTIGATION / FEASIBILITY STUDY STURGIS WELL FIELD STURGIS, MICHIGAN	WARZYN WARZYN ENGINEERING INC
Sheet Number 2 OF 20	Drawn By JC
Project Number 12686	Approved By Timothy J. Marks
6	Checked By TLM
WARZYN	Date 2-26-91



LEGEND

SW-1 SD-1 ▲ APPROXIMATE SURFACE WATER AND SEDIMENT SAMPLING LOCATION AND NUMBER

W-20PR (865.56) EXISTING MONITORING WELL LOCATION, NUMBER AND GROUNDWATER ELEVATION

PW-4 PRODUCTION WELL LOCATION AND NUMBER

RAILROAD TRACKS

PAVED ROAD

874 WATER TABLE CONTOUR (CONTOUR INTERVAL: 2 FT, DASHED WHERE INFERRED)

(ND) WELL NOT DRILLED BY THIS DATE

NOTES

1. SEE DRAWING 12686-5 FOR ADDITIONAL NOTES AND LEGEND.
2. WATER LEVELS MEASURED BY WARZYN ENGINEERING INC. ON APRIL 26, 1989.

north

0 600 1200

SCALE IN FEET

WATER TABLE MAP (APRIL 26, 1989)

REMEDIAL INVESTIGATION / FEASIBILITY STUDY
STURGIS WELL FIELD
STURGIS, MICHIGAN

Project Number 12686

Sheet Number 5 OF 20

9

WARZYN

WARZYN ENGINEERING INC.

Designed By

Drawn By JC

Checked By TEM

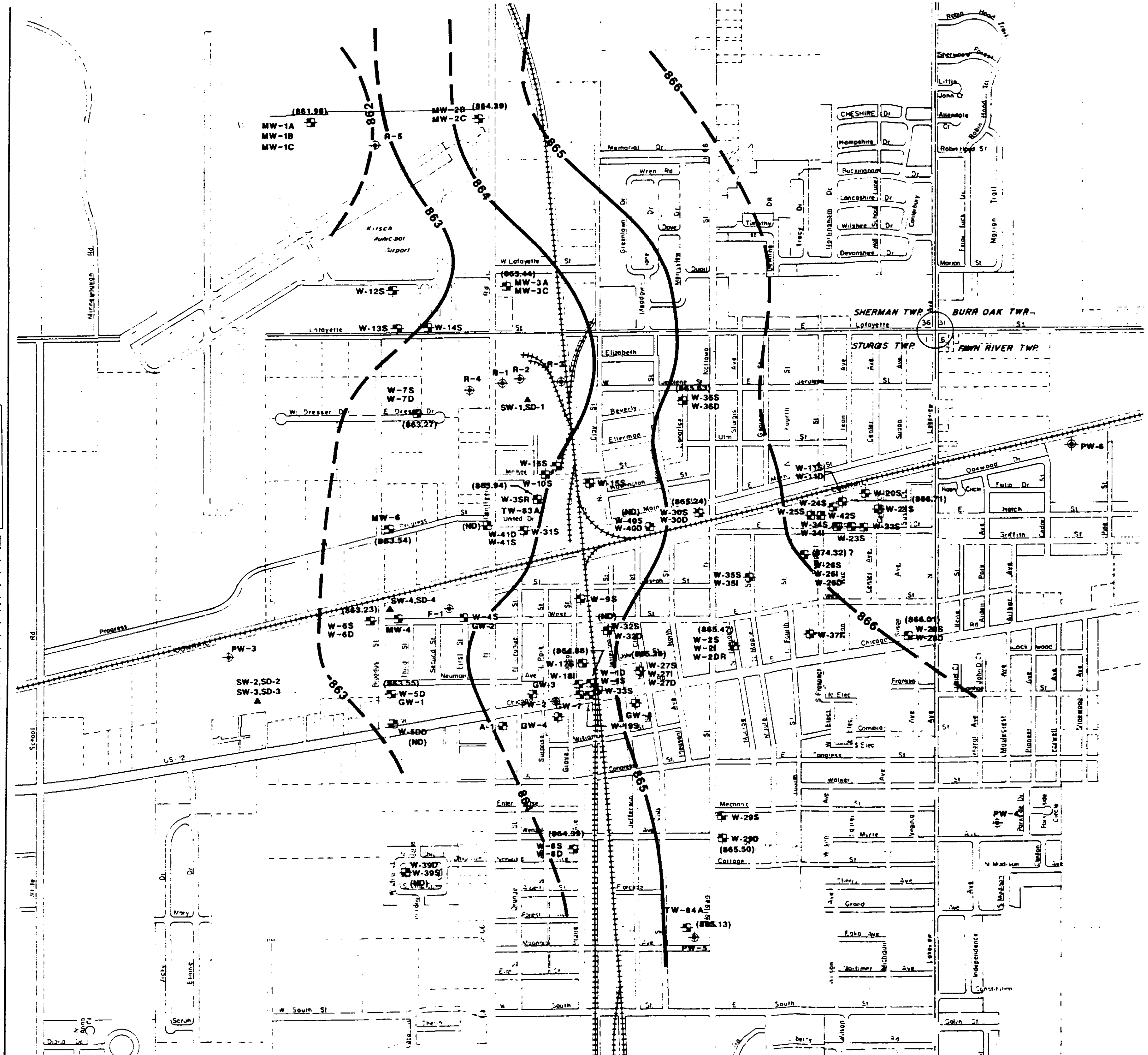
Approved By

Date 2-26-91

Reference

Revisions

Date · By · Appd



LEGEND

SW-1 SD-1 ▲	APPROXIMATE SURFACE WATER AND SEDIMENT SAMPLING LOCATION AND NUMBER
(865.47) W-2DR	EXISTING MONITORING WELL LOCATION, NUMBER AND POTENTIOMETRIC SURFACE ELEVATION
PW-4	PRODUCTION WELL LOCATION AND NUMBER, AND CONCENTRATION
	RAILROAD TRACKS
	PAVED ROAD
—866—	POTENTIOMETRIC SURFACE CONTOUR (CONTOUR INTERVAL: 1 FT, DASHED WHERE INFERRED)
(ND)	WELL NOT DRILLED BY THIS DATE

NOTES

1. SEE DRAWING 12686-5 FOR ADDITIONAL NOTES AND LEGEND.
2. WATER LEVELS MEASURED BY WARZYN ENGINEERING INC. ON APRIL 26, 1989.
3. THE POTENTIOMETRIC SURFACE ELEVATION OBTAINED ON APRIL 26, 1989 AT WELL W-26D MAY BE ERRONEOUS BASED ON DATA OBTAINED DURING OTHER MEASUREMENT EVENTS.

POTENTIOMETRIC SURFACE MAP (APRIL 26, 1989)

REMEDIAL INVESTIGATION / FEASIBILITY STUDY
STURGIS WELL FIELD
STURGIS, MICHIGAN

Revisions | Date · By · Appd

WARZYN
WARZYN ENGINEERING INC

Designed By
Drawn By JC
Checked By TEM
Approved By Timothy E. Mahon
Date 2-26-91
Reference

Printed
Sheet Number 9 OF 20
Project Number 12686
13

WARZYN

Volume I
Text, Tables,
Figures, &
Appendix A
70125

REMEDIAL INVESTIGATION
State Disposal Landfill
Plainfield Township
Kent County, Michigan

Prepared for:

Michigan Waste Systems, Inc.
Livonia, Michigan

Prepared by:

Warzyn Inc.
Novi, Michigan

November 1991

SECTION 3
REMEDIAL INVESTIGATIONS

3.1 INTRODUCTION

This Remedial Investigation (RI) of the State Disposal Landfill Site was performed consistent with work tasks and procedures presented in Warzyn's October 1989 Work Plan, and March 1990 Quality Assurance Project Plan (QAPP), approved by the MDNR, unless otherwise noted in this report. The activities included the drilling and installation of monitoring wells, aquifer testing, geotechnical testing, an elevation and location survey, water level measurements, groundwater sampling and data analysis. These activities were completed by Warzyn, Layne Northwest Water Supply Contractors (Layne), EWI Engineering Associates (EWI), and Holland Engineering.

The work tasks, personnel, and dates of performance were as follows:

- Drilling and monitoring well installation was performed by Layne and Warzyn from April 17, 1990 to July 19, 1990.
- Monitoring well development was performed by Layne and Warzyn from June 15 - 19, 1990 and June 26, 1990 to July 19, 1990.
- Geotechnical testing was performed by EWI from July 6 - 23, 1990.
- Aquifer testing was performed by Warzyn from July 30, 1990 to August 2, 1990.
- Water level measurements were taken by Warzyn on August 2, 1990 and September 25, 1990.
- Groundwater sampling was performed by Warzyn from August 20 - 29, 1990, September 4 - 13, 1990, and October 1 - 3, 1990.
- An elevation and location survey was performed by Holland Engineering from July 1990 to August 1990.

3.2 DRILLING, SAMPLING, AND MONITORING WELL INSTALLATION

3.2.1 Introduction

This section of the RI describes the drilling program, including geological logging, in-situ groundwater (vertical profile) sampling, geophysical logging, and monitoring well installation. Layne was contracted by Warzyn to conduct the drilling and monitoring well installation program. The drilling, sampling, and monitoring well installation program was performed from April 17, 1990 to July 19, 1990. Warzyn representatives monitored and recorded daily activities and provided guidance on monitoring well construction, sampling methods, and procedures.

3.2.2 Monitoring Well Location/Installation Rationale

In order to better define the hydrogeology and compound distribution, a new monitoring well network was installed to augment the existing wells on the State Disposal Landfill Site. Monitoring wells (MW) were installed at eight locations, as shown on Figure 2. The locations for the monitoring wells were determined during the Work Plan development in consultation with the MDNR. Warzyn obtained permission from private landowners to gain access to each of the well locations outside the MWSI property boundaries. Monitoring well locations were staked in the field by Warzyn and Layne personnel, and checked by representatives from utility companies.

Monitoring wells at three locations were installed to the south and west of the State Disposal Landfill (MW9S, MW9D, MW10, MW11) which are hydrogeologically upgradient of the landfill and Site (Figure 2). The remaining well locations (MW12, MW13, MW14, MW15S, MW15I, MW15D and MW16) are located downgradient (north and northeast) from the landfill and upgradient from the majority of affected residential wells (Figure 2).

The drilling program for installation of monitoring wells employed vertical profiling of groundwater quality using specific conductivity analyses and Gas Chromatograph (GC) field screening techniques. Final monitoring well depths and well clusters were based on the criteria described in the following paragraphs.

In general, monitoring wells were to be screened in zones corresponding to the highest concentrations of total VOCs and specific conductance, as determined in the field. If VOCs and specific conductance both peaked at the same depth in the aquifer, one well was installed. Where peak VOCs and specific conductance readings were detected at different elevations in the aquifer, a cluster of two or more monitoring wells were constructed and screened at the elevations of the peak VOC concentration and the peak conductance measurement. If VOCs and specific conductance readings did not indicate a contaminated zone in the aquifer, the screen was set at a depth below the water table comparable to existing monitoring wells immediately upgradient or downgradient.

If a substantial clay or silt layer (> 5 ft thick), potentially protecting a deeper zone or second aquifer, was encountered during the drilling operations, drilling continued based on GC results. If VOCs were detected within 20 ft above the clay, casing was installed in the borehole to minimize possible cross contamination between clean and contaminated formations in the aquifer.

The drilling and sampling continued to 50 ft below any contamination as determined by GC results, until subsurface conditions prevented the drilling operations from continuing further, or bedrock was encountered, or as otherwise directed by Warzyn's Site hydrogeologist.

In addition to the monitoring wells installed with screened intervals selected on the basis of field screening, three monitoring wells were installed to determine vertical gradients and deep groundwater quality. MW9D was installed to provide data upgradient from the landfill. MW15D and MW16 were installed at depths below contamination detected by field screening to confirm that contamination had not migrated to those depths and to determine vertical gradients at these locations.

3.2.3 Drilling Methods

A total of 2600 ft of drilling was performed by Layne from April 17, 1990 to July 19, 1990. Eleven soil borings (SB9, SB9S, SB10, SB11, SB12, SB13, SB14, SB15S, SB15I, SB15D, and SB16) were advanced using an air rotary technique known as the Dual Tube Reverse Air

Circulation method. Soil boring SB9D was advanced using a combination of conventional mud rotary and dual tube techniques. With the exception of SB9, these borings were completed as monitoring wells (designated as MW). Specific soil boring logs and monitoring well installation diagrams are provided in Appendix B.

The dual tube method consists of a 2.4-in. diameter tube that is inside a 4.5-in. diameter water-tight steel casing, or outer tube, with an annular space between them (Figure 6). The outer wall of the dual tube serves to case the borehole. The lead casing of the inner tube uses a tri-cone rotary bit for cutting soil materials. The relative positions of the two tubes are such that the leading edge of the bit is at the same depth or lags slightly behind the leading edge of the outer tube. High velocity compressed air or water is injected down the annular space along the outside of the inner tube and through the bit. The cuttings are carried to the surface via the inner tube. A top head drive rotates the entire drill string including the tri-cone rotary bit. Figure 6 illustrates the dual tube arrangement. Cuttings are conveyed to a cyclone where the air velocity is reduced, discharged out the top, and the solids (soil cuttings) fall into a 55-gallon drum. The high velocity of the air stream returns cuttings from depth to the surface with little discernible delay.

In order to provide a cavity to collect soil samples, construct a monitoring well, and/or to isolate formations, the dual tube method required the use of a separate casing, known as the overshot pipe. The overshot pipe is a steel casing with an inside diameter of approximately 5 in., which, depending on subsurface formation conditions, is installed around the outside of the dual tube by means of high pressure air and water, or drilling mud, and hydraulic pressure. The overshot casing was advanced to the depth of confining layers or to the depth required for well installation.

The overshot method was used to construct monitoring wells in each of the new soil borings except SB9 and SB10. Soil sampling was attempted in SB9, using the overshot method. However, due to subsurface formation conditions which caused the over-shot casing to become stuck in the borehole, this method was abandoned. Eventually, SB9 was abandoned after completion. In SB10, similar subsurface soil conditions were documented and a temporary 6-in casing was installed using a casing hammer apparatus. Soil sampling using the dual tube overshot casing method was only successful in SB15D. Details concerning the subsurface conditions are discussed in the Section 3.2.6, Soil Sampling.

SB9D was drilled and sampled using mud rotary and dual tube methods. Both drilling methods were utilized due to the continuing problem of the overshot casing becoming stuck in the borehole. In the mud rotary drilling technique, the dual tube casing string was converted to conventional mud rotary. A 7-in. tri-cone rotary bit was attached to the lead casing string, and a bentonite-based drilling mud was pumped directly down the dual tube casing and through the bit. Drilling mud serves several functions in the drilling. The mud: 1) cools and lubricates the drill bit, 2) stabilizes the borehole wall, 3) prevents inflow of formation fluids and, 4) minimizes cross contamination between formations.

The drilling muds circulated back to the surface by moving up the annular space between the outside of the dual tube and the wall of the borehole. At the surface, the fluid was discharged through a pipe and into a baffled sedimentation tank. The fluids overflow into a suction pit where a pump recirculated the fluid back through the dual tube.

Mud rotary was used to within 20 ft of the screened interval in SB9D. At this depth, the mud rotary technique was switched back to the dual tube reverse air rotary method to the terminus of borehole to avoid building a mud cake in the screened interval of the monitoring well.

3.2.4 Groundwater (Vertical Profile) Sampling

During the drilling operations, groundwater samples were collected to evaluate the vertical profile of groundwater quality. Upon reaching the water table, discrete groundwater samples were collected at 10-ft intervals through the dual tube. Vertical profiling was performed in soil borings SB9, SB10, SB11, SB12, SB13, SB14, SB15, and SB16.

At each sampling interval, the water level in the dual tube was measured with an electronic water level probe. The collection of a groundwater sample consisted of purging a minimum of three casing volumes from the dual tube by means of either a bailer or a small diameter (Keck) submersible sampling pump with a packer. The selection of sampling device was dictated by the turbidity and the recharge rates of groundwater into the dual tube. If no water was encountered, drilling proceeded.

A Keck pump equipped with a packer was used to purge and sample groundwater entering into the dual tube when: 1) groundwater was relatively silt- or sand-free, 2) groundwater levels were less than 160 ft below ground level (the effective operating range of the pump), and 3) the rate of recharge was sufficient to pump efficiently. The technique consisted of packing off the bottom 10 ft of the dual tube and purging three volumes of groundwater from the isolated interval. The Keck pump could be utilized when the sampling interval was less than 160 ft below the ground surface. When the sampling interval was deeper than 160 ft, the Keck pump was lowered into the dual tube as deep as possible, packed off, and as the water level was rising, the casing was evacuated and sampled. Upon evacuating the required amount of water from the casing, samples were collected from the pump discharge.

When recharge was slow, and the Keck pump was determined to be a less than efficient sampling technique, alternate methods were used. A stainless steel or PVC bailer was used to evacuate the required volume of groundwater. Water samples were then collected from the base of the water column with a stainless steel point source bailer.

An alternative method, which was used at the discretion of the Site hydrogeologist, was to purge the water column by circulating air and sampling from the base of the water column using a point source bailer. This method was utilized in extreme cases, when heaving sand flowed into the dual tube and prevented sampling with a bailer or Keck pump. Groundwater collection method at each interval is shown on Table 3-1.

3.2.5 Groundwater Analysis

A total of 87 groundwater samples were collected and analyzed for volatile organic compounds (VOCs) using a laboratory-grade Gas Chromatograph (GC), which provided immediate results as the drilling proceeded. The results are shown on Table 3-2. The GC was a Varian Model 3400 with PID and Hall detectors and a voltage regulator to protect the GC unit from potentially harmful electrical surges. Detection limits ranged from 1-5 parts per billion (ppb). The GC unit was set up and operated in the Site operations trailer by a Warzyn analytical chemist.

The samples were collected in 40-ml vials and placed into ice-filled coolers. The samples were immediately transported to the on-site GC unit. Specific conductance, pH, and temperature were also analyzed in the field at the drilling location. As a means of quality control, the GC and field measuring equipment were calibrated daily (as prescribed in Warzyn's March, 1990 QAPP). The results of these analyses were used to select the depths of screened intervals for the monitoring wells.

In addition, odor, turbidity, color, sampling times, sampling apparatus, and difficulties encountered were recorded in field notes. The results of the water quality field analysis during drilling are shown on Table 3-1.

Each groundwater sample was collected and analyzed by the GC in the above described manner, with the exception of the first three sampling intervals collected in SB9 (120 ft, 130 ft, and 140 ft). Drilling and sampling commenced before the GC unit was completely set up and properly calibrated. These three samples were collected and sent via overnight carrier to Warzyn's Analytical Laboratory and analyzed for the same constituents necessary for the vertical profiling. The results of these water quality field analyses and VOCs detected during drilling are shown on Tables 3-1 and 3-2.

3.2.6 Soil Sampling

The soil cuttings were visually classified using the United Soil Classification System (USCS) and continuously logged in the field by a Warzyn geologist. Representative samples were collected at intervals of 5 ft and have been saved for future examination. The air and soil discharge from the cyclone was monitored using an explosimeter and portable HNu photoionization detector (HNu). A record of these readings is included in the boring logs provided in Appendix B.

Split-spoon samples were attempted during the drilling operations. In order to provide a conduit to run drill rod with a split-spoon, the dual tube method required the use of the overshot pipe. At SB9, installation of the overshot pipe for split-spoon and Shelby tube sampling purposes was made. The technique required the drilling to stop at the sample interval and the overshot be installed around the outside of the dual tube to the depth required for sampling.

A number of attempts to install the casing at the first sampling interval and subsequent intervals were made during the drilling of the first borehole SB9. On the first few attempts, the overshot casing was washed in with water and high pressure. Due to the nature of the subsurface sands encountered in the drilling (fine, unsaturated sands which bound the casing when saturated with water), the overshot casing became stuck between 40 and 60 ft. When the casing was freed, subsequent attempts to continue washing in the casing with water ended with the same result. A decision to switch from water to bentonite mud (used only above the water table) was made by Warzyn and Layne personnel and approved by the MDNR. This time, the casing became stuck at 130 ft, and special hydraulic jacks were needed to free the casing.

Once the casing was free, drilling and water sampling continued to bedrock. Attempts to collect split-spoon or Shelby tube samples other than soil cuttings was abandoned for SB9. SB9 was drilled to bedrock, grouted, and abandoned.

To provide representative samples for geotechnical sampling under the drilling conditions encountered at this Site, split-spoon and Shelby tube samples were collected from the boreholes drilled for installation of MW9D and MW15D. These boreholes were drilled following completion of the original boreholes for vertical profiling of groundwater quality at these locations. In drilling the boreholes for MW9D and MW15D, soil sampling intervals and screened intervals were selected based on the results of the previous boreholes. The overshot casing was washed in using bentonite drilling mud to each selected sampling interval. At a depth of at least 15 ft above the screened interval, the drilling fluid was switched to potable water prior to installing the overshot casing to the total depth. Soil samples were collected by split-spoon or Shelby tubes attached to a string of drilling rod lowered through the overshot casing. A total of eight split-spoon samples were obtained from SB15D and SB9D. Two Shelby tube samples were obtained from SB9D.

Three split-spoon samples were recovered from SB9D and five samples were recovered from SB15D. The split-spoon samples from SB9D were obtained from 40 to 42 ft, corresponding with the unsaturated zone; 110 to 112 ft, corresponding with the approximate level of the water table; and 125 to 127 ft, corresponding with the screened interval of MW9S.

The split-spoon samples from SB15D were obtained from: 40 to 42 ft, corresponding to the unsaturated zone; 68 to 70 ft, corresponding to the water table; 120 to 122 ft, corresponding to the screened interval of MW15S; 148 to 150 ft, corresponding to the screened interval of MW15I; and 181 to 183 ft, corresponding to the screened zone of MW15D.

3.2.6.1 Geotechnical Testing

Eight split-spoon samples were collected by ASTM D1586 methods, examined by the hydrogeologist and submitted to EWI for grain size analysis and soil organic content analyses. This was done to better characterize the aquifer, and aid in interpreting possible contaminant migration within the aquifer on the Site and the study area. Geotechnical analyses were performed using ASTM or U.S. Army Engineers' Manual methods as presented in the QAPP. The results are presented in Appendix C.

Two Shelby tube samples (ASTM Method D1587-74) were recovered from clay zones in SB9D and submitted to EWI for falling head permeability testing. The samples were obtained from 160 to 162 ft and 220 to 222 ft. Permeability testing indicates the hydraulic conductivity of the clay and its effect on groundwater flow.

3.2.6.2 Gamma Logging

Upon the completion of drilling the initial deep soil borings, additional stratigraphic information was obtained from the borings with the use of natural gamma logging equipment. Gamma logging was used as an independent technique in conjunction with and to supplement visual logging of cuttings. The deep borings (SB9, SB10, SB11, SB12, SB13, SB14, SB15I, and SB16) were logged from the bottom up shortly after the appropriate boring completion depth was reached with the dual tube method. The gamma logging occurred through the dual tube. The gamma-ray log results were used in conjunction with water quality analyses to select the optimum depths of screened intervals for the monitoring wells.

Two existing wells in the study area were also gamma-logged. PZ1 and PZ2 were logged for comparison with the newly installed monitoring wells. The results of the gamma logging is shown in Appendix D.

3.2.7 Monitoring Well Installation

The screened intervals of the monitoring wells were selected based on the results of the vertical profiling. Monitoring well installation diagrams are provided in Appendix E. Monitoring wells MW10, MW11, MW12, MW13, MW14, MW15I, and MW16 were constructed in the initial deep boreholes (SB10, SB11, SB12, SB13, SB14, SB15I, and SB16). In preparation for monitoring well installation and before the overshot casing could be washed in, the dual tube had to be pulled up to the depth of the bottom of the screened interval. The open portion of the borehole below the screened interval had to be backfilled to created a stable base for the dual tube to set, while the overshot was washed in. Subsequently, this backfill served as the base for the monitoring well.

As the dual tube was pulled up the borehole to the depth of the bottom of the screen interval, the borehole cavity was sealed with a bentonite grout slurry to within 30 ft of the screened interval. Above the slurry, the borehole was backfilled with collapsed formation, or a combination of collapsed formation and silica sand to the depth desired for well construction.

Monitoring wells MW9S, MW9D, MW15S, and MW15D were drilled and installed after the initial drilling, groundwater sampling/vertical profiling, and GC analyses program had been completed. The screened intervals for these monitoring wells were predetermined prior to their construction, based on the vertical sampling results from the adjacent deep boreholes. These borings were drilled without sampling; the overshot casing washed in, the dual-tube pulled, and the well was constructed.

The dual tube was washed in using a bentonite mud to a depth at least 15 ft above the screened interval. At that point, the bentonite mud was switched to potable water and the casing was washed in to the desired depth. This procedure was followed when constructing MW9S, MW9D, MW11, MW12, MW13, MW14, MW15S, MW15I, MW15D, and MW16. MW10 was constructed through a temporary 6-in. casing driven with a casing hammer.

Upon reaching the desired screened interval with the overshot casing, the monitoring wells were constructed through the overshot casing. Specific well construction information and diagrams are presented in Appendix E and Table 2-1. The monitoring wells were constructed of 2-in. diameter Schedule 40, threaded, flushjoint, PVC well riser pipe, and a 5-ft stainless steel riser, above a 0.010-in. slot, 10-ft stainless steel well screen. Stainless steel centralizers were used to stabilize the riser pipe and screen in the borehole. Well pipe, screens and centralizers were steam-cleaned prior to installation, and handled with clean disposable surgical gloves, prior to and during installation.

The annulus between the well screen and the borehole was filled with #3 silica sand to at least 3 ft above the top of the well screen. A 2-ft thick fine silica sand seal was placed on top of the coarse sand filter pack to eliminate possible grout infiltration into filter pack, and the borehole was filled with a bentonite slurry grout up to within 2 ft of the top of the hole. After allowing the slurry to settle, dry granular bentonite was added on top of the slurry, as needed, to avoid bentonite slurry grout loss to the unsaturated formation. The top 2 to 3 ft of the well was filled with a concrete seal and protected with a 4-in. anodized aluminum casing and locking cap. The annular space between the casing and the PVC riser pipe was filled with coarse gravel to below the well cap and a weep hole was drilled near the bottom of the protective casing to allow fluids to drain from within the protective casing.

3.2.8 Development Procedures

The wells were developed after installation. Development procedures took place from June 15 to 19, 1990 and from June 26, 1990 to July 19, 1990. Development was accomplished by lowering into the well a brass and PVC pump and rod apparatus with a flexible hose attached below the pump. Rigid conduit, within which the rods to the pump operated and groundwater was discharged, held the pump in place. The rods were pulled up and down by a pumpjack, a beam with a counterweight run by a small electric motor.

A flexible hose attached below the pump was lowered to within 1 ft of the bottom of the well. A surging action was created in the well screen by turning the pump on and off. The wells were surged for approximately 15 minutes to 1/2 hour and then purged using the pumpjack and rod pump. Specific conductivities, pH, and temperatures were measured during the development procedures. The results are presented in Appendix F.

Development was considered complete when the purged water was visually clear, conductivities and pH stabilized, and a minimum of five well volumes of water plus the approximate volume of other fluids lost in the borehole within 20 ft above or below the screened interval while drilling were removed from the well. The development water from the wells was monitored with an HNu. Because HNu screening did not indicate readings greater than 5 ppm above background in any monitoring wells, development water was disposed on-Site.

3.2.9 Decontamination/Containment Procedures

Soil cuttings and liquids generated during the drilling operation were discharged from the cyclone directly into 55-gallon drums and screened with an HNu. Soil cuttings and liquids resulting from the drilling operations on private lands were contained and transported to a staging area located near the State Disposal Landfill on MWSI property. HNu screening of the spoils indicated readings of less than 5 ppm above background and were disposed on MWSI property.

Decontamination procedures consisted of steam cleaning the rig, drill rods, bits, dual-tube, casing, tools, etc. between boreholes and between drill locations. Development apparatus was also thoroughly steam cleaned between monitoring well locations. Decontamination occurred on a temporary decontamination pad located on MWSI property and constructed by Warzyn. The decontamination pad was constructed of 20 mil plastic sheeting underlain by a packed limestone gravel base and berms. The base was built with a gentle slope to one corner where a sump constructed out of a 55-gal drum was placed. A small electric pump was used to evacuate the drum when full. Waste water from the decontamination operation was contained and temporarily drummed. The waste water screening indicated levels of less than 5 ppm above background and was disposed on MWSI property.

Split-spoon samplers were decontaminated between samples using a trisodium phosphate (TSP) detergent solution and distilled water rinse.

3.3 ELEVATION AND LOCATION SURVEY

An elevation and location survey was performed by Holland Engineering. The survey was conducted to establish locations on a Site map and top of casing elevations of the new and old monitoring wells. Standard methods were used to survey the monitoring wells.

The survey established the location ($\pm$ 1.0 ft) and top of casing elevation ($\pm$ 0.01 ft) for the wells. The survey results were reduced to USGS datum, and are presented on Figure 2 and in Table 2-1.

3.4 AQUIFER TESTING

The characteristics of the saturated soils at the Site and within the study area were evaluated with in-situ hydrologic tests performed from July 30, 1990 to August 2, 1990. The hydrologic tests consisted of "rising head" slug tests, and were conducted in the new MWSI monitoring wells (MW9 through MW16), in existing MWSI monitoring wells (MW2, MW3S, MW3D, MW7S, MW7D, and PZ2) and in Plainfield Township monitoring wells (PT3, PT4, and PT7).

A "rising head" slug test is conducted by introducing a known quantity of air pressure into the well, displacing the static water level, allowing the water level to equilibrate to a pre-test level, quickly releasing the air pressure from the well and recording the rising water level, or head, changes with time. The data for the test was measured using a sensitive pressure transducer and recorded using an In Situ Hermit electronic data logger. A FORTRAN program, developed by Warzyn, was used to reduce and interpret the field test data using a version of the Thiem equation. The program utilizes the method of Bouwer and Rice (1976), as modified in Bouwer (1989), to interpret the water level versus time data obtained from the rising head slug test. Results are presented on Table 3-3 and in Appendix G. Details of hydraulic conductivity test methods are also presented in Appendix G.

STATE DISPOSAL LANDFILL SITE RI/FS
Data Use and Data Quality Objectives for Field Gas Chromatography

The intended data use and DQO's for Field GC at the State Disposal Landfill Site RI/FS as described in the QAPP were as follows:

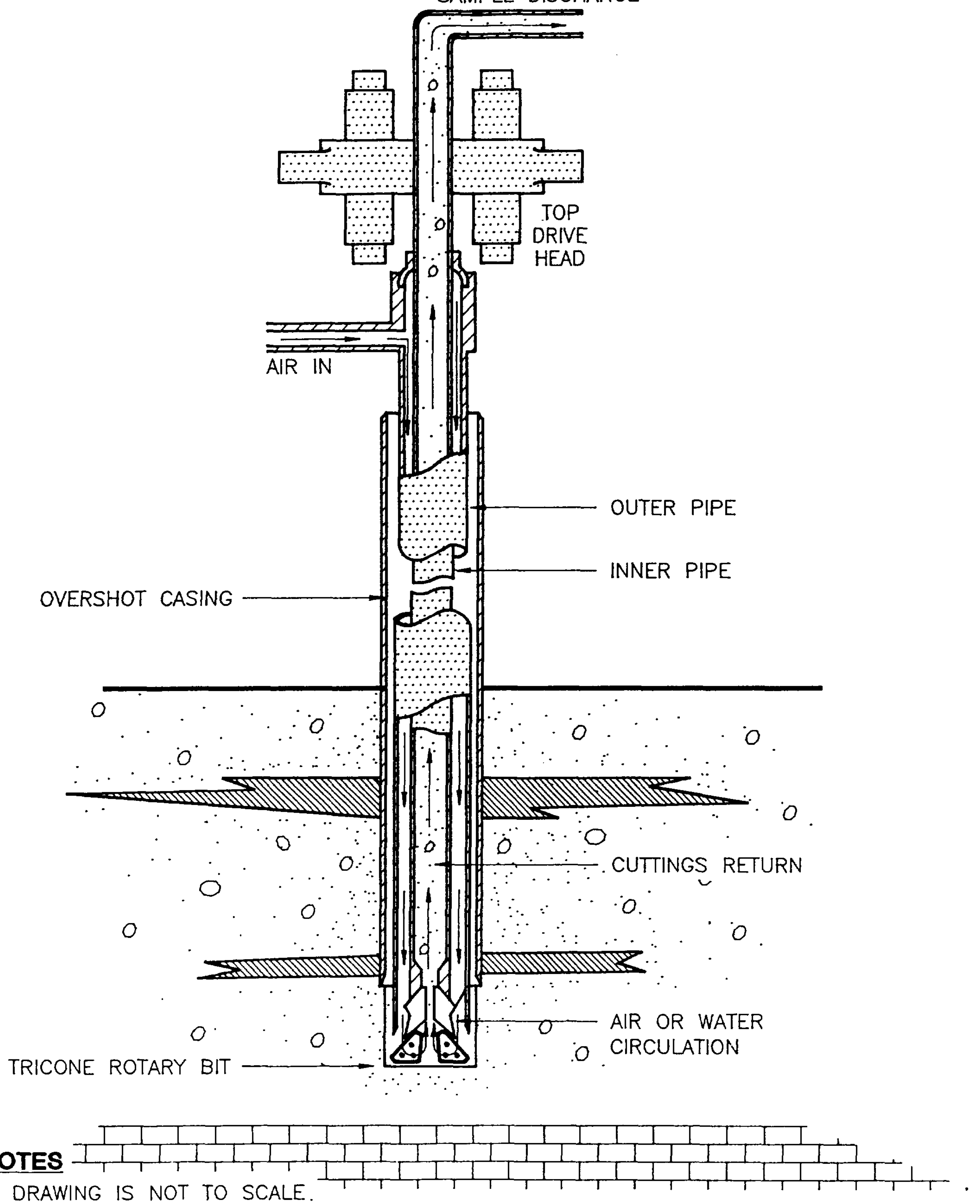
- A total of 15 organic compounds were included as target compounds in the GC screening method.

- The groundwater sample Field GC results would be used with field specific conductivity results to create vertical profiling of groundwater quality, and as a guide for monitoring well screen placement.

- Field GC concentration results would be considered estimated, and compound identification would be considered tentative.

- Quality control would consist of the analysis of duplicate samples (results within 15% RPD), and continuing calibration standard analyses (results within 30% RPD).

QUALITY CONTROL
INITIALS DATE / INITIALS DATE
'ting Standards SJL 1-30-91PM JFG 1-31-91
Lead Professional EVW 1-30-91 Division
Section Other



NOTES

1. DRAWING IS NOT TO SCALE.
2. DRAWING MODIFIED FROM STRAUSS, et al. (1989).

FIGURE 6

WARZYN	**DUAL-TUBE REVERSE AIR ROTARY METHOD**	Drawn SJL	Checked EVW/DEP	App'd. [illegible]
	REMEDIAL INVESTIGATION STATE DISPOSAL LANDFILL PLAINFIELD TOWNSHIP KENT COUNTY, MICHIGAN	Revisions		Date 10/31/91
				70125 **A10**

Ground Water Sampling by Dual Tube Drilling

Using this method eliminates cross-contamination

By Lori Huntoon Pencak

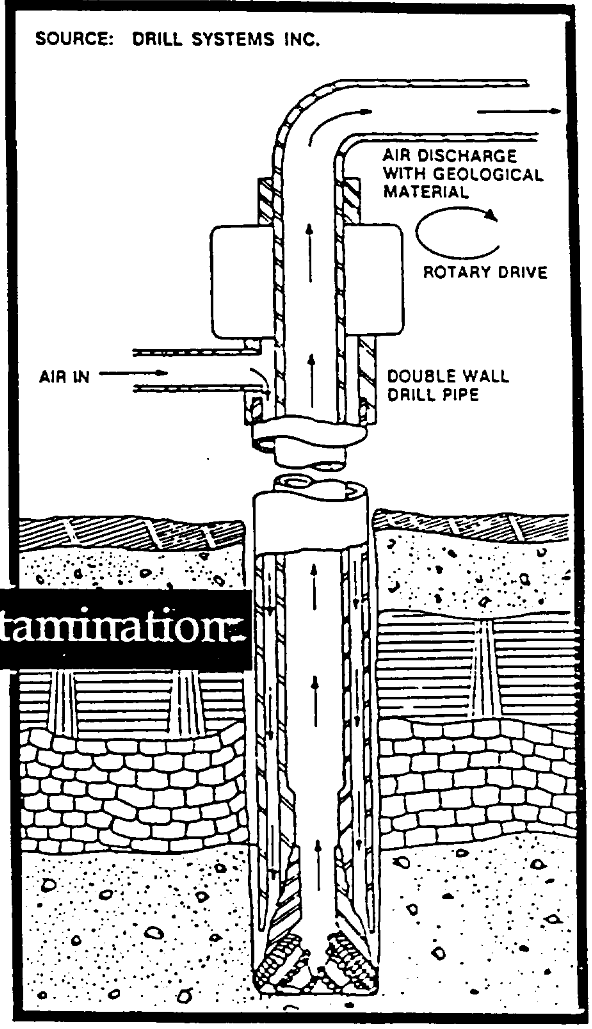


Figure 1. In reverse circulation sampling, air is injected down the outer annulus of dual-walled pipe, causing air and samples to flow up the inner pipe.

One of the most challenging tasks facing the ground water professional is evaluating the vertical distribution of subsurface contamination. Dual tube drilling methods allow the collection of ground water samples with depth during drilling, and minimize cross-contamination while providing site-specific information within the borehole.

Collecting ground water samples with depth is useful not only in detecting the contamination, but also as a design tool for monitoring systems. Multiple monitoring nests are often installed in the initial phase of a hydrogeologic investigation in an attempt to evaluate the distribution of vertical contamination.

A common problem which arises is the improper vertical placement of screened intervals, due to lack of existing site information. One approach to designing a monitor well network is the collection of ground water samples with depth during well installation.

The use of screened hollow stem augers has proven to be very useful in this type of ground water sampling. However, the utility of the dual tube drilling method is quickly being understood as an extremely efficient and cost-effective method for determining specific aquifer information from the collection of ground water samples with depth.

Dual Tube Methods

Dual tube drilling, also called reverse circulation drilling and center sampling recovery, provides the collection of continuous representative samples from a borehole with virtually no cross-contamination of the samples. In addition to the collection of geological samples, ground water samples also can be collected from the borehole during drilling operations in order to determine differences in contaminant concentrations with depth.

This is possible due to the unique design of the drilling system. Dual tube drilling uses rotary drilling methods, including either a rotary bit or down-the-hole hammer to advance through the formation. The flush-threaded, dual-walled pipe is joined to the bit by a drill bit sub, and both are advanced simultaneously (see figure 1).

The drilling fluid, preferably air or mist, is forced down the outer annulus of the dual-walled pipe, and directed to the center of the pipe. The size of the borehole is such that there is a minimal clearance between the bit and the drilling pipe, which minimizes cross-contamination along the annulus of the borehole.

The cuttings are discharged through the inner annulus to the surface within fractions of a second, allowing immediate determination of the lithology. It also is important to note that formation

(Continued on next page)

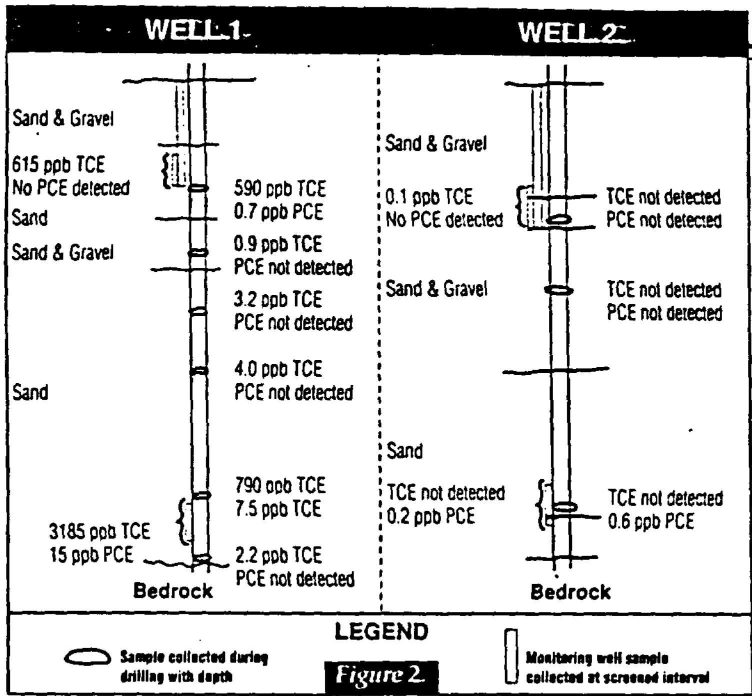


Figure 2.

cuttings and ground water samples don't come into contact with the overlying borehole materials.

During drilling, ground water samples can be collected at selected intervals as the borehole is advanced. Due to the design of the system, ground water is allowed to enter only through the open bottom of the borehole. Thus, the sample collected is representative of the actual ground water in the formation at the open interval.

Samples can be collected by lowering a pump intake line or a bailer through the inner tube of the drilling column. Several volumes of water may be removed prior to collection in order to insure a representative sample.

When using a bailer, lower and raise the bailer slowly with a smooth motion to avoid volatilization of potential contaminants. When using a pump, don't allow the intake line to extend to the bottom of the drilling tools — rather, place the line several feet above the bottom.

If possible, use a photoionization meter during drilling and sampling procedures, and screen the samples prior to submitting them to the laboratory. It's helpful to the lab if you can estimate whether the sample will have high or low detects of contaminants. High levels of contaminants when not expected can result in laboratory equipment being shut down for days in order to decontaminate the machines.

Samples can be collected in VOA vials and immediately analyzed by gas chromatography methods in the field, and/or transported to a laboratory for analysis. It's best to collect at least two vials for each sample, to allow for sample breakage and unexpected analytical duplicates. Additional samples can be collected for field screening, indicator parameters (pH, specific conductance, temperature) and additional laboratory analyses.

Properly label the sample bottles with the well number, sample depth, date and time. Samples should be immediately stored on ice and warmed to room temperature prior to analysis.

During the collection of ground water samples, stringent decontamination procedures should be followed. These include:

- Washing the sampling equipment with laboratory-grade detergent and several rinses with distilled water between each sample.
- Replacing the rope or tubing after each sample collection.
- Using gloves when handling the sampling equipment or bottles.

It's important to note that in fine-grained formations, bridging of sand in the drilling tools may not allow the collection of a ground water sample.

Case Study

A subsurface investigation was completed to determine the source

Do's and Dont's for Collecting Samples When Using Dual Tube Drilling

- DO decontaminate the sampling equipment thoroughly between each sample.
- DO replace the bailer rope or plastic tubing between each sample.
- DON'T surge the bailer up and down. Lower and raise the bailer into the well slowly with a smooth motion to ensure a representative sample and to avoid volatilization of potential contaminants.
- DO collect at least two vials for each sample to allow for sample bottle breakage and unexpected analytical duplicates.
- DO use a field ionization meter to screen the samples before submitting them to the laboratory. It will help if you can estimate if the sample will have high or low detects of contaminants.
- DO label the samples immediately after collection. Place the samples on ice, complete the necessary chain of custody records and transport the samples to the laboratory as soon as possible.
- DO use cross-section maps in addition to tables to evaluate the results received from the use of vertical sampling with depth during drilling. ❑

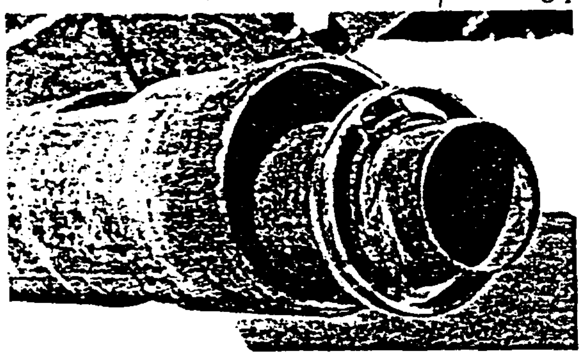
and extent of a trichloroethylene (TCE) ground water contaminant plume. Several deep monitoring wells were installed at the site, using the dual tube method.

Water quality samples were collected at 20 foot intervals to a depth of 150 feet in order to determine the variations in ground water quality with depth.

Concentrations of contaminants were detected at two distinct depths within the aquifer, which may have been missed during the installation of a standard monitoring network due to improper vertical placement of screened intervals. Figure 2 shows the results of the samples which were collected from two of these wells during drilling.

The contaminant plumes detected during the investigation may have been missed during the installation of a standard monitoring network due to improper placement of screened intervals. Figure 3 shows the hypothetical placement of a screen in coarse material overlying bedrock.

However, in this case, the contaminant plume wasn't located directly above the bedrock, but rather tens of feet above it. The installation of a screen in the coarse material would indicate a lack of contamination (as shown in the collection of the sample at depth in figure 2).



An end section of reverse circulation drill pipe.

In addition, concentrations of the contaminant in between these plume areas were minimal or nonexistent, insuring that cross-contamination between the samples was minimized.

Evaluating the vertical distribution of contamination with depth is critical in determining the appropriate screen depths of monitoring wells. The collection and analysis of ground water samples with selected depths during drilling provides the water professional with a definition of ground water quality with vertical distance.

And the most efficient and cost-effective method of collecting ground water samples with depth is through the dual tube drilling method, which allows collection of the samples at selected depths while minimizing the chance of cross-contamination. ❑

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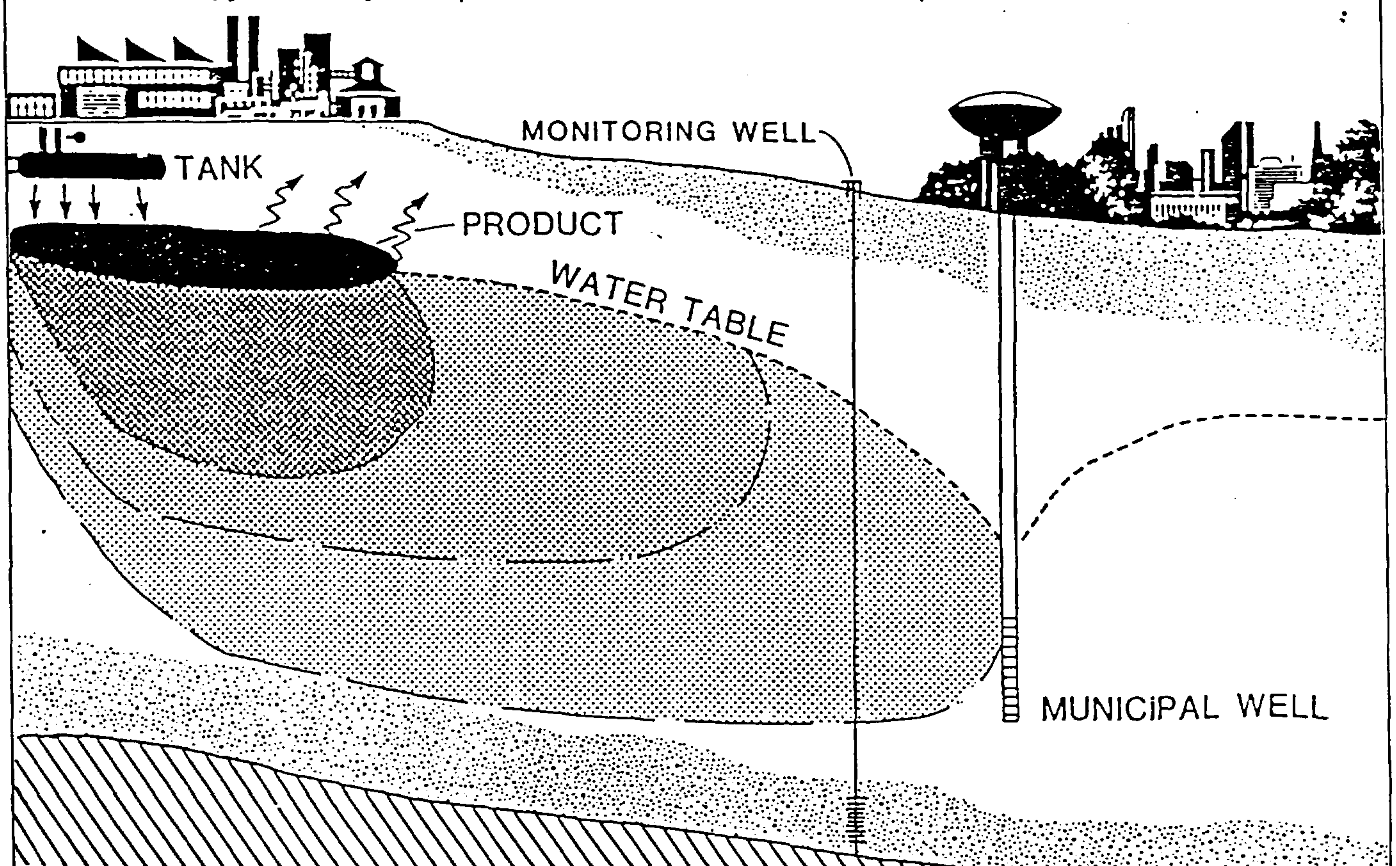

Figure 3. Specific placement of monitoring wells is necessary to determine the extent of a contaminant plume.